Machinery MESsages

Shaft versus housing measurements

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In the last issue, we provided some guidelines for measuring shaft relative versus shaft absolute vibration. Because more people are becoming interested in monitoring essential and general purpose machinery in addition to their critical machines, we have received several requests to address a related, equally important, issue — when to measure shaft vibration (either relative or absolute) and when to measure machine housing or casing vibration.

This column will discuss the proper selection of housing or shaft measurement transducers for vibration *monitoring,* as opposed to *analysis,* on rotating machinery. The criteria for transducer selection and signal conditioning/readout can be quite different for monitoring versus analysis, even on the same machine.

Machinery monitoring dictates a transducer which provides the most significant output signal when the machine has a problem. The following three primary factors must be evaluated when selecting transducers for a monitoring system:

Economic considerations. This defines the reasonable upper limits for capital investment in monitoring instrumentation for various classes of machinery. The considerations for a given machine include:

1. Importance to the total plant process.
2. Maintenance costs.
3. Personnel and plant safety.
4. Spare parts requirements.
5. Insurance coverage.
6. Cost of extended machine downtime in the event of a serious mechanical failure.

All potential machine problems. From the list of all potential problems for a given machine, those which are likely to occur most frequently must be defined (or at least estimated). Considerations include:

1. Process or service.
2. Operating conditions as compared to original design parameters.
3. Type of machine components, such as bearings, seals, foundations, couplings, etc.
4. Relationship to coupled or adjacent machinery.

Vibration characteristics. These should be determined for two conditions:

1. Vibration characteristics of the machine in the absence of problems.
2. Vibration characteristics that change under malfunction conditions.

Meaningful Information

When choosing between shaft and housing measurement transducers, the machine problem and vibration characteristics can be restated: Which vibration measurement, shaft or housing, will provide more meaningful information concerning both the normal and malfunction conditions of the machine? Under normal conditions (usually low vibration), which part of the machine, the shaft or housing, will produce the most significant vibration? The word, "significant," means meaningful or informative, concerning the object being measured, and implies using the transducer with the best signal-to-noise ratio.

When considering machine problems, you must also answer: Under malfunction conditions (usually, but not always, high vibration), which part of the machine, the shaft or housing, will produce the most significant (usually largest) *change* in vibration?

Obviously, the more common malfunctions on most classes of machinery are rotor-related. That is, the problem (unbalance, misalignment, rubs, etc.) either originates at or is manifested by a change in rotor (shaft) vibration. Frequently-occuring malfunctions originate at the machine housing or casing only in isolated situations.

For most applications, therefore, it seems logical that a shaft vibration measurement would be preferred. However, in certain machine designs, some of the vibration originating at the shaft is transmitted to some degree to the bearing housing. Thus, the ultimate

question is: *For a given machine, can rotor vibration be detected only by direct measurement of the shaft, or does the bearing housing measurement faithfully represent rotor-transmitted vibration?*

Whether a machine exhibits more vibration amplitude (and more meaningful vibration data) at the shaft or the housing is primarily determined by one or both of the following factors:

1. The relative stiffness (or compliance) of the bearing and its support.
2. The mass ratio between the rotor and the stationary machine components (housing/casing).

In order to keep from writing a textbook on the mechanical design of rotating machinery, perhaps the concepts can be illustrated by the following examples.

Case one

A machine may exhibit both shaft relative and casing absolute vibration in significant amplitudes. In general, if one amplitude is at least 20 percent of the other, then both should be considered significant. For this application, a dual probe should be used with the casing absolute velocity signal integrated to displacement and added (instantaneous time summation) to the shaft relative displacement signal to yield shaft absolute displacement.

These machines typically include, but may not be limited to, medium and large steam turbogenerators (especially the low pressure and high pressure cases), large gas turbines (especially the exhaust bearing sections), and some large fans.

Case two

Machines with rolling element bearings have virtually no shaft motion relative to the bearing (measured at the bearing) under normal operation because the bearing, by design, is effectively a zero clearance device. Granted, as a bearing begins to fail and clearances increase, shaft motion relative to the bearing or bearing support may be measured by a proximity probe. But this situation provides little *advance* warning of the impending problem.

Because most of the shaft vibration is transmitted to the bearing housing on these machines, velocity transducers can be used in conjunction with a dual path monitor. (Refer to Bently Nevada Applications Note, "Dual Path Monitor." To order, check L0096 on the return card.)

Accelerometers may be used, but double integration to displacement becomes difficult, especially at low frequencies. Displacement is desirable because it is more representative of shaft-related vibrations caused by unbalance, misalignment, etc. On the other hand, an accelerometer (and dual path monitor) may be the only viable option when the frequencies of interest exceed the capability of the velocity transducer (usually above 1 kHz).

An exception in this machine category is a rolling element bearing with a squeeze film damper. Here, proximity probes mounted to the outer bearing housing will be more meaningful. Another exception is machinery which can be evaluated by the Bently Nevada Rolling Element Bearing Activity Monitor (REBAM™). For more information on the REBAM, check L0472 on the return card.

Case three

A machine with fluid film bearings may exhibit small or no shaft relative motion. Virtually all or most of the shaft vibration energy is transmitted directly to the bearing and bearing housing, and, therefore, measurements should be made at those locations.

As stated previously, these machines have compliant bearing supports and/or low case-to-rotor mass ratios. These machines include large fans (massive rotating elements) and machines with vertically-supported pillow block or pedestal bearings (compliant supports).

Case four

The above cases relate to selecting transducers for a *monitoring* system. Recall that most monitoring systems are somewhat of a compromise between providing economical monitoring and a sufficient degree of protection against the majority of, but perhaps not all, potential machinery malfunctions. Therefore, a machine may have one type of transducer for continuous monitoring, but may require another type of transducer for analysis if an unusual malfunction occurs.

In addition, it is often useful to make *any and all* possible measurements on a machine in applications requiring information beyond overall vibration amplitude (which is provided by the monitoring system).

Periodic surveys of machine vibration characteristics require the evaluation of frequency, phase angle, etc., in addition to amplitude. In this case, it is also informative to compare shaft and housing vibration characteristics. Obviously, for diagnosing a machine with a suspected malfunction, any and all measurements may be necessary to determine the nature, source, and severity of the problem.

Comparing measurements

The best method by which to determine whether shaft or housing measurement is required is to take some actual measurements on the installed machine in the field. Three pieces of information are needed:

1. Shaft vibration relative to the housing.
2. Housing absolute vibration.
3. Shaft absolute vibration (the instantaneous time summation of #1 and #2 above).

Measurement of shaft vibration relative to the housing can be obtained by using a fabricated bracket or temporary (but solid) mount for a proximity probe. Housing absolute vibration measurement can be made using a velocity transducer (signal integrated to displacement). The velocity transducer may be handheld, but is preferably mounted with a magnetic base, stud or bolted flange. The mounting location should be directly on the machine part supporting the proximity probe mount, at the same lateral location and angular orientation of the probe.

Measurement of shaft absolute vibration can be derived from the first two measurements using a differential summing amplifier, the signal conditioning of a Bently Nevada Dual Probe Monitor, a TK-20 Portable Vector Filter Machinery Balancing and Diagnostic Kit, or by visual observation and graphical resolu-

tion of the two timebase waveforms using an oscilloscope.

Actually, if any two of the three measurements can be made, the third measurement can be derived from visual observations on the oscilloscope. It is sometimes difficult to temporarily and effectively install a proximity probe, especially on a running machine! On the other hand, it is usually easy to measure housing absolute vibration on a bearing housing.

Shaft absolute motion sometimes can be made with a velocity sensor mounted on a "shaft stick" or "fishtail." However, in order for the shaft stick measurement to be valid for comparison with the shaft absolute vibration and final derivation of the shaft vibration relative to the housing, the shaft area that is used to make the measurement must be close to the same lateral location as the housing-mounted sensor. Often, the available exposed shaft area is too far removed from the bearing journal to provide comparative information.

(Note: Use extreme caution when taking readings with a hand-held shaft stick or fishtail. Be sure the shaft area is smooth, and free from keyways, etc. Clean the shaft surface first and add some lubricant, then make certain the shaft is *turning away* from you before taking any measurements. Also, whenever comparing readings from any two transducers, be sure that the readings are evaluated over a similar frequency range for both transducers.)

Footnote to last issue

As a result of our previous column, which compared the Bently Nevada Dual Probe and a shaft rider, it has been suggested that we include an additional explanation. In some installations, the available machine housing component for mounting the Dual Probe is not directly attached or referenced to the bearing itself.

For these applications, the average radial shaft position information provided by the proximity probe may not be meaningful as a measurement of shaft position in the bearing. This information may also be affected by any steady-state movement of the proximity probe mounting, e.g., a bearing housing which expands thermally relative to the shaft average position which, in effect, causes the probe to "move away" from the shaft. In this application, also, it will be difficult to maintain the original reference of the "cold probe gap" for average shaft radial position measurements.

Additional information on the applications explained above can be obtained by checking the following L numbers on the return card:

Applications Note: Justification of Monitoring, L0466.

Applications Note: Choosing the Proper System, L0467.

Applications Note: Specific Machinery Types, L0468.

39158 General Purpose Velocity Transducer, L0456.

90410-01 Three-Channel Velocity Monitor, L0455.

TK-20 Turnable Filter Machinery Balancing and Diagnostic Kit, L0392.

Rolling Element Bearing Activity Monitor, L0472.

26530 Dual Probe/Housing Assembly, L0002.

72564 Dual Probe Monitor, L0100.

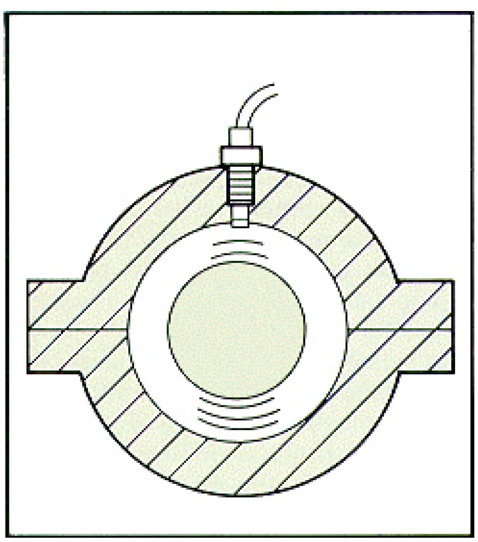

Figure 1.
- Shaft vibration relative to bearing housing: Significant.
- Bearing housing absolute vibration: Little or none.
- Required measurement: Proximity probe.

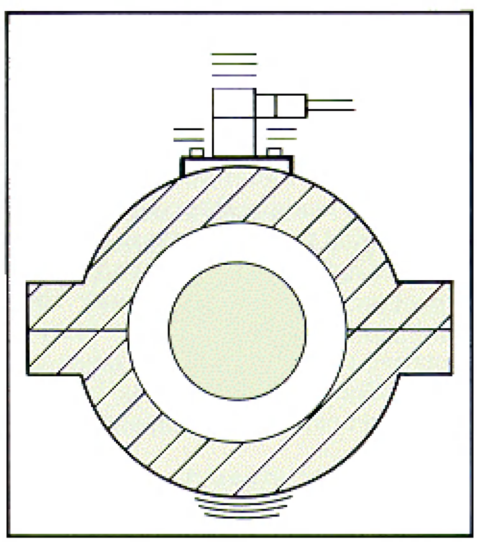

Figure 2.
- Shaft vibration relative to bearing housing: Little or none.
- Bearing housing absolute vibration: Significant.
- Measurement required: Seismic transducer (velocity or acceleration).

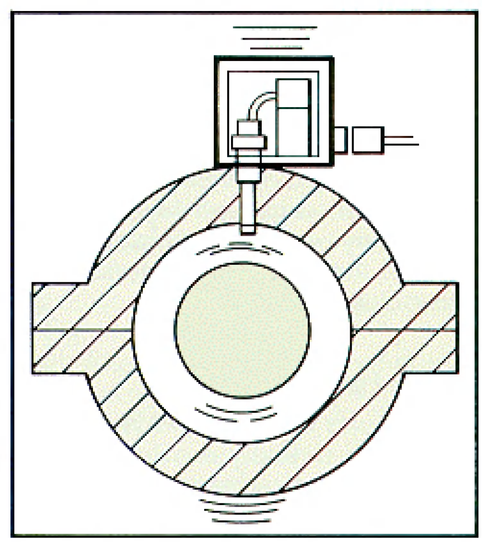

Figure 3.
- Shaft vibration relative to bearing housing: Significant.
- Bearing housing absolute vibration: Significant.
- Required measurement: Dual probe.

Note: Vertical motion is shown in the figures only as an example.